# CHAPTER V - SUMMARY OF FORECAST VERIFICATION

## 1. ANNUAL FORECAST VERIFICATION

### a. WESTERN NORTH PACIFIC OCEAN

Verification of warnings at initial, 24-, 48- and 72-hour forecast positions was made against the final best track. The (scalar) forecast, along-track and cross-track errors (illustrated in Figure 5-1) were then calculated for each tropical cyclone and are presented in Tables 5-1A, 5-1B, 5-1C and 5-1D, as appropriate. The frequency distributions of forecast errors in 30 nm (56 km) increments for 24-, 48-, and 72-hour forecasts are in Figures 5-2A through 5-2C, respectively. A summation of the mean forecast errors, since 1971, is shown in Table 5-2A. Table 5-2B includes mean along-track and cross-track forecast errors for 1988. A comparison of the annual mean forecast errors for all tropical cyclones as compared to those tropical cyclones that reached typhoon intensity can be seen in Table 5-3. The mean forecast errors for 1988 as compared to the nineteen previous years are graphed in Figure 5-3.

### b. NORTH INDIAN OCEAN

The positions given for warning times and those at the 24-, 48-, and 72-hour valid times were verified for tropical cyclones in the North Indian Ocean by the same methods used for the western North Pacific. These error statistics should not be taken as representative of any trend due to the small sample number. Table 5-4 is the initial and forecast along-track and cross-track error summary for the North Indian Ocean. Table 5-5A contains a summary of the annual mean forecast errors for each year. Table 5-5B includes along-track and cross-track errors for 1988. Forecast errors are plotted in Figure 5-4 (Seventy-two hour forecast errors were evaluated for the first time in 1979). There were no verifying 72-hour forecast in 1983 and 1985.

### c. SOUTH PACIFIC AND SOUTH INDIAN OCEANS

The positions given for warning times and those at the 24-, 48-, and 72-hour valid times were verified for tropical cyclones in the Southern Hemisphere by the same methods used for the western North Pacific. It should be noted that due to the lack of verifying ground-truth data, these error statistics should not be taken as representative of any trend. Table 5-6A is the initial, forecast along-track and cross-track error summary for the southern hemisphere. Table 5-6B has the number of warnings verified at each forecast period. Table 5-7A contains a summary of the annual mean forecast errors for each year. Table 5-7B includes along- and cross-track errors for 1988. Forecast errors are plotted in Figure 5-5.

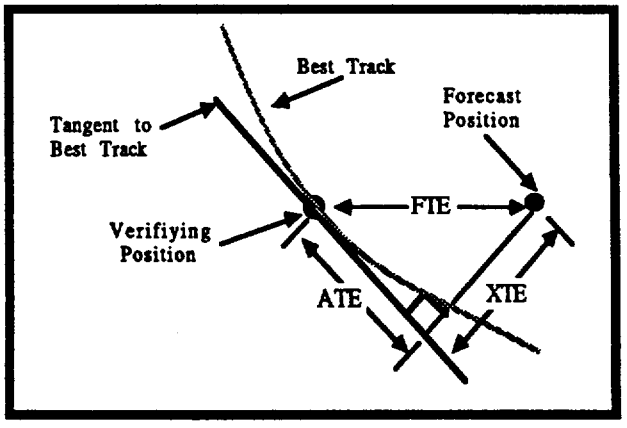



Figure 5-1. Definition of cross-track error (XTE), along-track error (ATE) and forecast track error (FTE). In this example, the XTE is positive (to the right of the best track) and the ATE is negative (behind or slower than the best track).

TABLE 5-1A

**INITIAL POSITION ERROR SUMMARY**
**WESTERN NORTH PACIFIC OCEAN**
**1988 SIGNIFICANT TROPICAL CYCLONES**

| TROPICAL CYCLONE | | ERROR (NM) | SAMPLE SIZE |
|---|---|---|---|
| (01W) | TY ROY | 13 | 41 |
| (02W) | TY SUSAN | 18 | 17 |
| (03W) | TD 03W | 19 | 6 |
| (04W) | TY THAD | 24 | 20 |
| (05W) | TS VANESSA | 27 | 11 |
| (06W) | TY WARREN | 19 | 30 |
| (07W) | TS AGNES | 33 | 8 |
| (08W) | TS BILL | 12 | 5 |
| (09W) | TS CLARA | 24 | 6 |
| (10W) | TY DOYLE | 14 | 24 |
| (11W) | TS ELSIE | 28 | 6 |
| (11W) | TS ELSIE* | 27 | 4 |
| (12W) | TY FABIAN | 21 | 18 |
| (13W) | TS GAY | 33 | 6 |
| (14W) | TY HAL | 18 | 37 |
| (01C) | TY ULEKI | 17 | 21 |
| (15W) | TS IRMA | 17 | 16 |
| (16W) | TS JEFF | 15 | 9 |
| (17W) | TS KIT | 26 | 12 |
| (18W) | TS LEE | 21 | 15 |
| (19W) | TS MAMIE | 36 | 4 |
| (20W) | STY NELSON | 10 | 30 |
| (21W) | TY ODESSA | 16 | 22 |
| (22W) | TY PAT | 17 | 17 |
| (23W) | TY RUBY | 24 | 30 |
| (24W) | TY SKIP | 18 | 30 |
| (25W) | TY TESS | 14 | 10 |
| (26W) | TS VAL | 57 | 10 |
| TOTALS | | 23 | 465 |

* REGENERATED

TABLE 5-1B

**SUMMARY OF 24-HOUR FORECAST ERRORS**
**WESTERN NORTH PACIFIC OCEAN**
**1988 SIGNIFICANT TROPICAL CYCLONES**

| TROPICAL CYCLONE | | FORECAST ERROR (NM) | ALONG-TRACK ERROR MEAN* | ALONG-TRACK ERROR MEDIAN | CROSS-TRACK ERROR MEAN* | CROSS-TRACK ERROR MEDIAN | SAMPLE SIZE |
|---|---|---|---|---|---|---|---|
| (01W) | TY ROY | 123 | 104 | -28 | 47 | 13 | 37 |
| (02W) | TY SUSAN | 146 | 100 | -85 | 85 | -32 | 13 |
| (03W) | TD 03W | 169 | 127 | ** | 104 | ** | 4 |
| (04W) | TY THAD | 143 | 103 | -95 | 90 | -49 | 16 |
| (05W) | TS VANESSA | 194 | 180 | ** | 54 | ** | 7 |
| (06W) | TY WARREN | 86 | 61 | -25 | 46 | 24 | 28 |
| (07W) | TS AGNES | 322 | 271 | ** | 134 | ** | 5 |
| (08W) | TS BILL | 119 | 106 | ** | 52 | ** | 3 |
| (09W) | TS CLARA | 89 | 36 | ** | 79 | ** | 3 |
| (10W) | TY DOYLE | 106 | 82 | -50 | 61 | -50 | 20 |
| (11W) | TS ELSIE | 283 | 250 | ** | 104 | ** | 2 |
| R(11W) | TS ELSIE | 129 | 127 | ** | 19 | ** | 2 |
| (12W) | TY FABIAN | 141 | 94 | -46 | 77 | 9 | 14 |
| (13W) | TS GAY | 98 | 64 | ** | 66 | ** | 3 |
| (14W) | TY HAL | 122 | 89 | -76 | 61 | -16 | 33 |
| (01C) | TY ULEKI | 82 | 47 | 4 | 58 | 24 | 19 |
| (15W) | TS IRMA | 76 | 42 | 11 | 54 | -1 | 14 |
| (16W) | TS JEFF | 64 | 47 | ** | 34 | ** | 5 |
| (17W) | TS KIT | 96 | 58 | ** | 63 | ** | 8 |
| (18W) | TS LEE | 127 | 110 | -101 | 41 | -29 | 11 |
| (19W) | TS MAMIE | *** | *** | *** | *** | *** | 0 |
| (20W) | STY NELSON | 64 | 45 | -11 | 34 | -11 | 26 |
| (21W) | TY ODESSA | 100 | 56 | -52 | 75 | -29 | 18 |
| (22W) | TY PAT | 140 | 110 | -110 | 60 | 37 | 13 |
| (23W) | TY RUBY | 109 | 82 | -17 | 53 | 0 | 26 |
| (24W) | TY SKIP | 99 | 85 | -5 | 41 | 7 | 29 |
| (25W) | TY TESS | 57 | 49 | ** | 24 | ** | 8 |
| (26W) | TS VAL | 228 | 152 | ** | 146 | ** | 6 |
| TOTALS | | 114 | 85 | -45 | 58 | -9 | 373 |

* THE MEAN WAS COMPUTED FROM ABSOLUTE VALUES.
** THE MEDIAN WAS NOT COMPUTED FOR INSTANCES OF TEN CASES OR LESS.
*** FORECASTS WERE NOT ISSUED OR DID NOT VERIFY.
R = REGENERATED

1. THE MEAN IS THE SUM OF ALL THE VALUES DIVIDED BY THE NUMBER OF OBSERVATIONS.
2. THE MEDIAN IS THE MIDDLE VALUE OF THE SAMPLE.
3. THE ALONG-TRACK ERROR COMPONENT IS HOW FAR THE WARNING POSITION WAS DISPLACED AHEAD OR BEHIND THE BEST TRACK POSITION. THE SAMPLE CONSISTS OF TWO PARTS: THE MEAN (DISTANCE) AND THE MEDIAN (NEGATIVE VALUES WERE BEHIND TRACK OR SLOW, AND POSITIVE VALUES WERE AHEAD OF TRACK OR FAST).
4. THE CROSS-TRACK ERROR COMPONENT IS HOW FAR THE WARNING POSITION WAS DISPLACED TO THE LEFT OR RIGHT OF THE BEST TRACK POSITION. THE SAMPLE CONSISTS OF TWO PARTS: THE MEAN (DISTANCE) AND THE MEDIAN (NEGATIVE VALUES WERE LEFT OF TRACK AND POSITIVE VALUES WERE RIGHT OF TRACK).

TABLE 5-1C

**SUMMARY OF 48-HOUR FORECAST ERRORS**
**WESTERN NORTH PACIFIC OCEAN**
**1988 SIGNIFICANT TROPICAL CYCLONES**

| TROPICAL CYCLONE | FORECAST ERROR (NM) | ALONG-TRACK ERROR MEAN* | ALONG-TRACK ERROR MEDIAN | CROSS-TRACK ERROR MEAN* | CROSS-TRACK ERROR MEDIAN | SAMPLE SIZE |
|---|---|---|---|---|---|---|
| (01W) TY ROY | 246 | 196 | -62 | 119 | 22 | 33 |
| (02W) TY SUSAN | 378 | 344 | ** | 106 | ** | 9 |
| (03W) TD 03W | *** | *** | *** | *** | *** | 0 |
| (04W) TY THAD | 274 | 233 | -223 | 123 | -81 | 12 |
| (05W) TS VANESSA | 386 | 352 | ** | 158 | ** | 3 |
| (06W) TY WARREN | 152 | 118 | -52 | 74 | 56 | 23 |
| (07W) TS AGNES | 714 | 706 | ** | 108 | ** | 1 |
| (08W) TS BILL | *** | *** | *** | *** | *** | 0 |
| (09W) TS CLARA | *** | *** | *** | *** | *** | 0 |
| (10W) TY DOYLE | 316 | 258 | -173 | 155 | -173 | 16 |
| (11W) TS ELSIE | *** | *** | *** | *** | *** | 0 |
| R(11W) TS ELSIE | *** | *** | *** | *** | *** | 0 |
| (12W) TY FABIAN | 177 | 108 | ** | 124 | ** | 10 |
| (13W) TS GAY | *** | *** | *** | *** | *** | 0 |
| (14W) TY HAL | 249 | 194 | -122 | 130 | -71 | 29 |
| (01C) TY ULEKI | 146 | 92 | 49 | 94 | 42 | 15 |
| (15W) TS IRMA | 94 | 76 | ** | 45 | ** | 10 |
| (16W) TS JEFF | 103 | 91 | ** | 48 | ** | 1 |
| (17W) TS KIT | 120 | 68 | ** | 98 | ** | 4 |
| (18W) TS LEE | 221 | 186 | ** | 89 | ** | 7 |
| (19W) TS MAMIE | *** | *** | *** | *** | *** | 0 |
| (20W) STY NELSON | 128 | 88 | 8 | 70 | -48 | 22 |
| (21W) TY ODESSA | 245 | 217 | ** | 109 | ** | 10 |
| (22W) TY PAT | 303 | 269 | ** | 110 | ** | 9 |
| (23W) TY RUBY | 162 | 121 | -90 | 75 | 13 | 22 |
| (24W) TY SKIP | 199 | 164 | -84 | 85 | 53 | 21 |
| (25W) TY TESS | 123 | 109 | ** | 53 | ** | 4 |
| (26W) TS VAL | 768 | 75 | ** | 764 | ** | 1 |
| TOTALS | 216 | 170 | -100 | 103 | -14 | 262 |

* THE MEAN WAS COMPUTED FROM ABSOLUTE VALUES.
** THE MEDIAN WAS NOT COMPUTED FOR INSTANCES OF TEN CASES OR LESS.
*** FORECASTS WERE NOT ISSUED OR DID NOT VERIFY.
R = REGENERATED

SEE TABLE 5-1B FOR EXPLANATIONS OF THE TERMS MEAN, MEDIAN, ALONG-TRACK ERROR AND CROSS-TRACK ERROR.

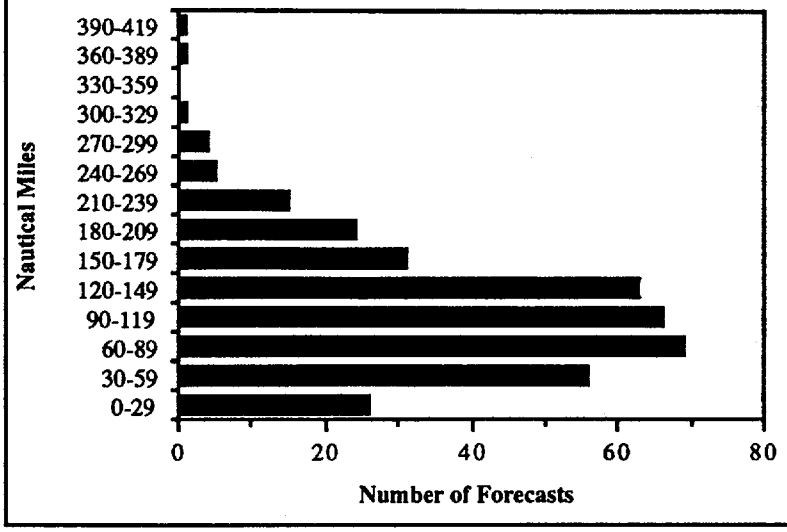
TABLE 5-1D

**SUMMARY OF 72-HOUR FORECAST ERRORS**
**WESTERN NORTH PACIFIC OCEAN**
**1988 SIGNIFICANT TROPICAL CYCLONES**

| TROPICAL CYCLONE | FORECAST ERROR (NM) | ALONG-TRACK ERROR MEAN* | ALONG-TRACK ERROR MEDIAN | CROSS-TRACK ERROR MEAN* | CROSS-TRACK ERROR MEDIAN | SAMPLE SIZE |
|---|---|---|---|---|---|---|
| (01W) TY ROY | 401 | 313 | -150 | 202 | 77 | 29 |
| (02W) TY SUSAN | 423 | 385 | ** | 121 | ** | 5 |
| (03W) TD 03W | *** | *** | *** | *** | *** | 0 |
| (04W) TY THAD | 329 | 315 | ** | 75 | ** | 8 |
| (05W) TS VANESSA | *** | *** | *** | *** | *** | 0 |
| (06W) TY WARREN | 246 | 193 | -106 | 113 | 96 | 16 |
| (07W) TS AGNES | *** | *** | *** | *** | *** | 0 |
| (08W) TS BILL | *** | *** | *** | *** | *** | 0 |
| (09W) TS CLARA | *** | *** | *** | *** | *** | 0 |
| (10W) TY DOYLE | 626 | 516 | -517 | 297 | -517 | 11 |
| (11W) TS ELSIE | *** | *** | *** | *** | *** | 0 |
| R(11W) TS ELSIE | *** | *** | *** | *** | *** | 0 |
| (12W) TY FABIAN | 279 | 256 | ** | 91 | ** | 6 |
| (13W) TS GAY | *** | *** | *** | *** | *** | 0 |
| (14W) TY HAL | 355 | 298 | -124 | 151 | -104 | 25 |
| (01C) TY ULEKI | 153 | 80 | 78 | 120 | 39 | 11 |
| (15W) TS IRMA | 158 | 39 | ** | 135 | ** | 6 |
| (16W) TS JEFF | *** | *** | *** | *** | *** | 0 |
| (17W) TS KIT | *** | *** | *** | *** | *** | 0 |
| (18W) TS LEE | 265 | 236 | ** | 104 | ** | 3 |
| (19W) TS MAMIE | *** | *** | *** | *** | *** | 0 |
| (20W) STY NELSON | 148 | 92 | 15 | 103 | -79 | 18 |
| (21W) TY ODESSA | 686 | 544 | ** | 398 | ** | 5 |
| (22W) TY PAT | 436 | 366 | ** | 235 | ** | 5 |
| (23W) TY RUBY | 210 | 112 | -105 | 156 | 28 | 18 |
| (24W) TY SKIP | 260 | 202 | -194 | 143 | 138 | 17 |
| (25W) TY TESS | *** | *** | *** | *** | *** | 0 |
| (26W) TS VAL | *** | *** | *** | *** | *** | 0 |
| TOTALS | 315 | 244 | -159 | 159 | -11 | 183 |

* THE MEAN WAS COMPUTED FROM ABSOLUTE VALUES.
** THE MEDIAN WAS NOT COMPUTED FOR INSTANCES OF TEN CASES OR LESS.
*** NOT ENOUGH WARNINGS WERE ISSUED TO VERIFY THE FORECAST.
R = REGENERATED

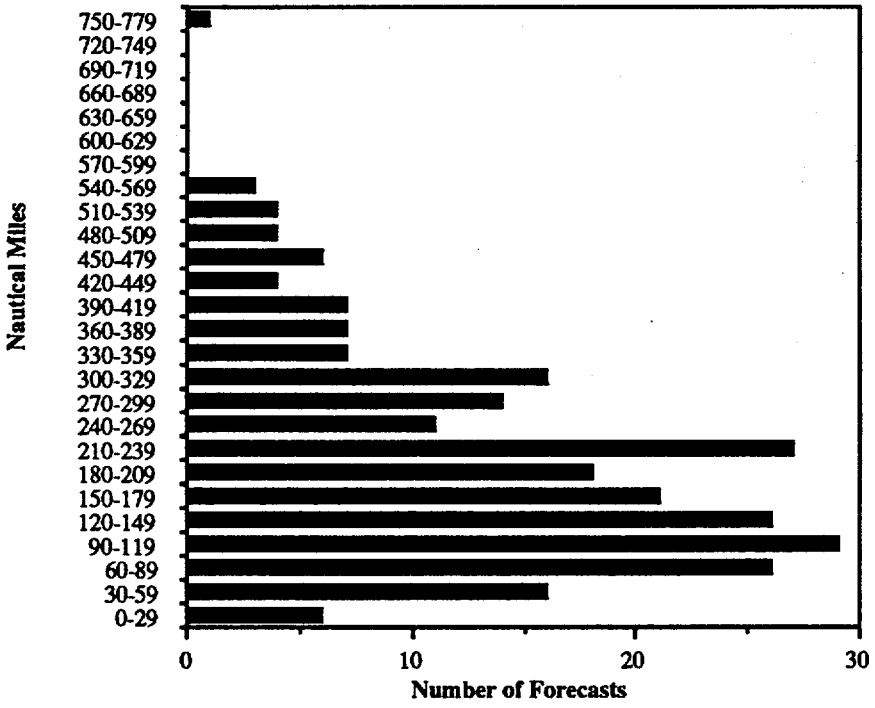
SEE TABLE 5-1B FOR EXPLANATIONS OF THE TERMS MEAN, MEDIAN, ALONG-TRACK ERROR AND CROSS-TRACK ERROR.




**24-HOUR FORECAST ERRORS (NM)**

| | |
|---|---|
| MEAN: | 114 |
| MEDIAN: | 113 |
| STANDARD DEVIATION: | 73 |
| CASES: | 373 |

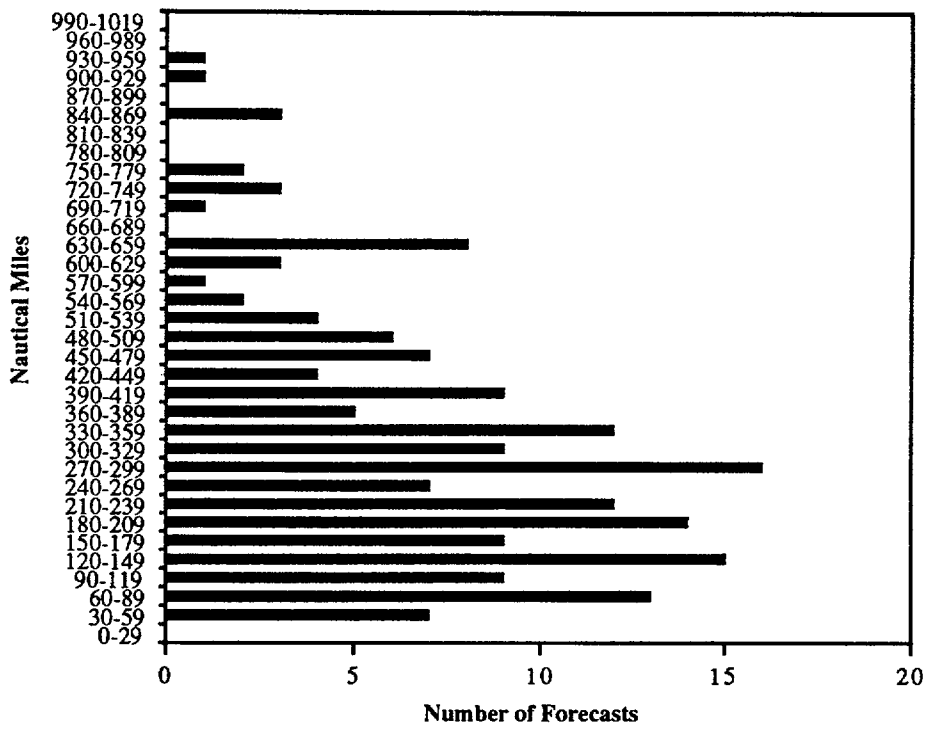
Figure 5-2A. Frequency distribution of the 24-hour forecast errors in 30 nm (56 km) increments for all significant tropical cyclones in the western North Pacific during 1988.




**48-HOUR FORECAST ERRORS (NM)**

| | |
|---|---|
| MEAN: | 216 |
| MEDIAN: | 212 |
| STANDARD DEVIATION: | 139 |
| CASES: | 262 |

Figure 5-2B. Frequency distribution of the 48-hour forecast errors in 30 nm (56 km) increments for all significant tropical cyclones in the western North Pacific during 1988.




**72-HOUR FORECAST ERRORS (NM)**

| | |
|---|---|
| **MEAN:** | **315** |
| **MEDIAN:** | **309** |
| **STANDARD DEVIATION:** | **202** |
| **CASES:** | **183** |

Figure 5-2C. Frequency distribution of the 72-hour forecast errors in 30 nm (56 km) increments for all significant tropical cyclones in the western North Pacific during 1988.

TABLE 5-2A

**ANNUAL MEAN FORECAST ERRORS FOR THE WESTERN NORTH PACIFIC**

| YEAR | 24-HOUR FORECAST | 24-HOUR RIGHT-ANGLE | 48-HOUR FORECAST | 48-HOUR RIGHT-ANGLE | 72-HOUR FORECAST | 72-HOUR RIGHT-ANGLE |
|---|---|---|---|---|---|---|
| 1971 | 111 | 64 | 212 | 118 | 317 | 117 |
| 1972 | 117 | 72 | 245 | 146 | 381 | 210 |
| 1973 | 108 | 74 | 197 | 134 | 253 | 162 |
| 1974 | 120 | 78 | 226 | 157 | 348 | 245 |
| 1975 | 138 | 84 | 288 | 181 | 450 | 290 |
| 1976 | 117 | 71 | 230 | 132 | 338 | 202 |
| 1977 | 148 | 83 | 283 | 157 | 407 | 228 |
| 1978 | 127 | 75 | 271 | 179 | 410 | 297 |
| 1979 | 124 | 77 | 226 | 151 | 316 | 223 |
| 1980 | 126 | 79 | 243 | 164 | 389 | 287 |
| 1981* | 123 | 75 | 220 | 119 | 334 | 168 |
| 1982* | 113 | 67 | 237 | 139 | 341 | 206 |
| 1983* | 117 | 72 | 259 | 152 | 405 | 237 |
| 1984* | 117 | 66 | 233 | 137 | 363 | 231 |
| 1985* | 117 | 66 | 231 | 134 | 367 | 214 |
| 1986 | 121 | ** | 261 | ** | 394 | ** |
| 1987 | 107 | ** | 204 | ** | 303 | ** |
| 1988 | 114 | ** | 216 | ** | 315 | ** |

* THE TECHNIQUE FOR CALCULATING RIGHT-ANGLE ERROR WAS REVISED IN 1981. THEREFORE, A DIRECT COMPARISON IN RIGHT-ANGLE ERROR STATISTICS CANNOT BE MADE BETWEEN ERRORS COMPUTED BEFORE 1981 AND THOSE COMPUTED SINCE 1981.

** IN 1986, RIGHT-ANGLE ERROR WAS REPLACED BY CROSS-TRACK ERROR. (SEE FIGURE 5-1B FOR THE DEFINITION OF CROSS-TRACK ERROR).

TABLE 5-2B

**1988 MEAN FORECAST, ALONG-TRACK AND CROSS-TRACK ERRORS FOR THE WESTERN NORTH PACIFIC OCEAN (ERRORS IN NM)**

| FORECAST | FORECAST ERROR | ALONG-TRACK ERROR MEAN | ALONG-TRACK ERROR MEDIAN | CROSS-TRACK ERROR MEAN | CROSS-TRACK ERROR MEDIAN |
|---|---|---|---|---|---|
| 24-HOUR | 114 | 85 | -45 | 58 | -9 |
| 48-HOUR | 216 | 170 | -100 | 103 | -14 |
| 72-HOUR | 315 | 244 | -159 | 159 | -11 |

TABLE 5-3

**ANNUAL MEAN FORECAST ERRORS (NM) WESTERN NORTH PACIFIC**

| YEAR | 24-HOUR ALL | 24-HOUR / TYPHOONS* | 48-HOUR ALL | 48-HOUR / TYPHOONS* | 72-HOUR ALL | 72-HOUR / TYPHOONS* |
|---|---|---|---|---|---|---|
| 1959 | | 117** | | 267** | | |
| 1960 | | 177** | | 354** | | |
| 1961 | | 136 | | 274 | | |
| 1962 | | 144 | | 287 | | 476 |
| 1963 | | 127 | | 246 | | 374 |
| 1964 | | 133 | | 284 | | 429 |
| 1965 | | 151 | | 303 | | 418 |
| 1966 | | 136 | | 280 | | 432 |
| 1967 | | 125 | | 276 | | 414 |
| 1968 | | 105 | | 229 | | 337 |
| 1969 | | 111 | | 237 | | 349 |
| 1970 | 104 | 98 | 190 | 181 | 279 | 272 |
| 1971 | 111 | 99 | 212 | 203 | 317 | 308 |
| 1972 | 117 | 116 | 245 | 245 | 381 | 382 |
| 1973 | 108 | 102 | 197 | 193 | 253 | 245 |
| 1974 | 120 | 114 | 226 | 218 | 348 | 357 |
| 1975 | 138 | 129 | 288 | 279 | 450 | 442 |
| 1976 | 117 | 117 | 230 | 232 | 338 | 336 |
| 1977 | 148 | 140 | 283 | 266 | 407 | 390 |
| 1978 | 127 | 120 | 271 | 241 | 410 | 459 |
| 1979 | 124 | 113 | 226 | 219 | 316 | 319 |
| 1980 | 126 | 116 | 243 | 221 | 389 | 362 |
| 1981 | 123 | 117 | 220 | 215 | 334 | 342 |
| 1982 | 113 | 114 | 237 | 229 | 341 | 337 |
| 1983 | 117 | 110 | 259 | 247 | 405 | 384 |
| 1984 | 117 | 110 | 233 | 228 | 363 | 361 |
| 1985 | 117 | 112 | 231 | 228 | 367 | 355 |
| 1986 | 121 | 117 | 261 | 261 | 394 | 403 |
| 1987 | 107 | 101 | 204 | 211 | 303 | 318 |
| 1988 | 114 | 107 | 216 | 222 | 315 | 327 |

* FORECASTS WERE VERIFIED WHEN THE TROPICAL CYCLONE INTENSITIES WERE OVER 35 KT (18 M/SEC).

** FORECAST POSITIONS NORTH OF 35 DEGREES NORTH LATITUDE WERE NOT VERIFIED.

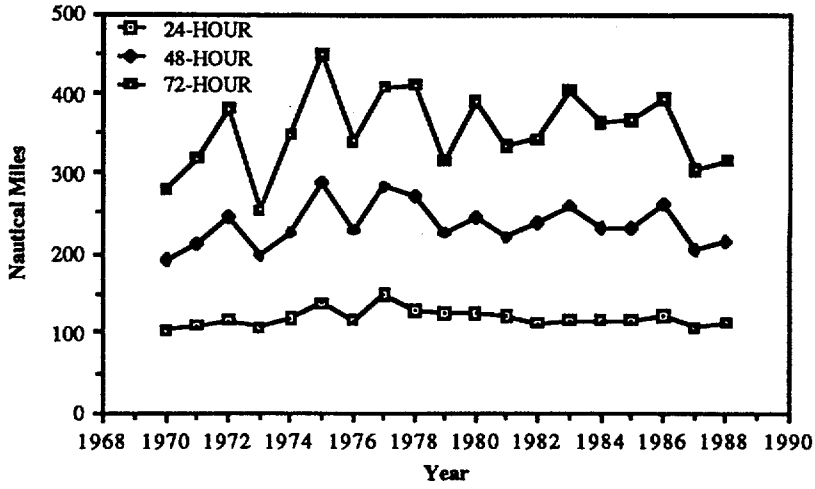



Figure 5-3. Annual mean forecast errors (nm) for all significant tropical cyclones in the western North Pacific.

TABLE 5-4

**FORECAST ERROR SUMMARY FOR THE NORTH INDIAN OCEAN**
**1988 SIGNIFICANT TROPICAL CYCLONES**

| TROPICAL CYCLONE | INITIAL POSITION ERROR (NM) | NUMBER OF WARNINGS |
|---|---|---|
| TC 01A | 61 | 10 |
| TC 02B | 30 | 3 |
| TC 03B | 28 | 3 |
| TC 04B | 22 | 22 |
| TC 05B | 37 | 6 |

24-HOUR FORECASTS

| TROPICAL CYCLONE | FCST ERROR | ALONG-TRACK ERROR MEAN | ALONG-TRACK ERROR MEDIAN | CROSS-TRACK ERROR MEAN | CROSS-TRACK ERROR MEDIAN |
|---|---|---|---|---|---|
| TC 01A | 188 | 172 | ** | 58 | ** |
| TC 02B | -- | -- | -- | -- | -- |
| TC 03B | -- | -- | -- | -- | -- |
| TC 04B | 90 | 64 | -55 | 48 | -10 |
| TC 05B | 171 | 92 | ** | 143 | ** |

48-HOUR FORECASTS

| TROPICAL CYCLONE | FCST ERROR | ALONG-TRACK ERROR MEAN | ALONG-TRACK ERROR MEDIAN | CROSS-TRACK ERROR MEAN | CROSS-TRACK ERROR MEDIAN |
|---|---|---|---|---|---|
| TC 01A | 484 | 155 | ** | 456 | ** |
| TC 02B | -- | -- | -- | -- | -- |
| TC 03B | -- | -- | -- | -- | -- |
| TC 04B | 186 | 107 | -62 | 141 | -100 |
| TC 05B | -- | -- | -- | -- | -- |

72-HOUR FORECASTS

| TROPICAL CYCLONE | FCST ERROR | ALONG-TRACK ERROR MEAN | ALONG-TRACK ERROR MEDIAN | CROSS-TRACK ERROR MEAN | CROSS-TRACK ERROR MEDIAN |
|---|---|---|---|---|---|
| TC 01A | -- | -- | -- | -- | -- |
| TC 02B | -- | -- | -- | -- | -- |
| TC 03B | -- | -- | -- | -- | -- |
| TC 04B | 409 | 227 | -213 | 303 | -306 |
| TC 05B | -- | -- | -- | -- | -- |

** THE MEDIAN WAS NOT COMPUTED FOR INSTANCES OF TEN CASES OR LESS.

TABLE 5-5A

**ANNUAL MEAN FORECAST ERRORS FOR THE NORTH INDIAN OCEAN**

| YEAR | 24-HOUR FORECAST | 24-HOUR RIGHT-ANGLE | 48-HOUR FORECAST | 48-HOUR RIGHT-ANGLE | 72-HOUR FORECAST | 72-HOUR RIGHT-ANGLE |
|---|---|---|---|---|---|---|
| 1971* | 232 | --- | 410 | --- | --- | --- |
| 1972* | 224 | 101 | 292 | 112 | --- | --- |
| 1973* | 182 | 99 | 299 | 160 | --- | --- |
| 1974* | 137 | 81 | 238 | 146 | --- | --- |
| 1975 | 145 | 99 | 228 | 144 | --- | --- |
| 1976 | 138 | 108 | 204 | 159 | --- | --- |
| 1977 | 122 | 94 | 292 | 214 | --- | --- |
| 1978 | 133 | 86 | 202 | 128 | --- | --- |
| 1979 | 151 | 99 | 270 | 202 | 437 | 371 |
| 1980 | 115 | 73 | 93 | 87 | 167 | 126 |
| 1981** | 109 | 65 | 176 | 103 | 197 | 73 |
| 1982** | 138 | 66 | 368 | 175 | 762 | 404 |
| 1983** | 117 | 46 | 153 | 67 | --- | --- |
| 1984** | 154 | 71 | 274 | 127 | 388 | 159 |
| 1985** | 123 | 51 | 242 | 109 | --- | --- |
| 1986 | 134 | *** | 168 | *** | 269 | *** |
| 1987 | 144 | *** | 205 | *** | 305 | *** |
| 1988 | 120 | *** | 219 | *** | 409 | *** |

* THE WESTERN BAY OF BENGAL AND ARABIAN SEA WERE NOT INCLUDED IN THE JTWC AREA OF RESPONSIBILITY UNTIL THE 1975 TROPICAL CYCLONE SEASON.

** THE TECHNIQUE FOR CALCULATING RIGHT-ANGLE ERROR WAS REVISED IN 1981. THEREFORE, A DIRECT COMPARISON IN RIGHT-ANGLE ERROR STATISTICS CANNOT BE MADE BETWEEN ERRORS COMPUTED BEFORE 1981 AND THOSE COMPUTED SINCE 1981.

*** IN 1986, RIGHT-ANGLE ERROR WAS REPLACED BY CROSS-TRACK ERROR. (SEE TABLE 5-1B FOR THE DEFINITION OF CROSS-TRACK ERROR).

TABLE 5-5B

**1988 MEAN FORECAST, ALONG-TRACK AND CROSS-TRACK ERRORS (NM) NORTH INDIAN OCEAN**

| TIME | FORECAST ERROR | ALONG-TRACK ERROR MEAN | ALONG-TRACK ERROR MEDIAN | CROSS-TRACK ERROR MEAN | CROSS-TRACK ERROR MEDIAN |
|---|---|---|---|---|---|
| 24-HOUR | 120 | 89 | -68 | 63 | -34 |
| 48-HOUR | 219 | 112 | -39 | 176 | -142 |
| 72-HOUR | 409 | 227 | -213 | 303 | -306 |

SEE TABLE 5-1B FOR EXPLANATIONS OF ALONG-TRACK ERROR AND CROSS-TRACK ERROR.

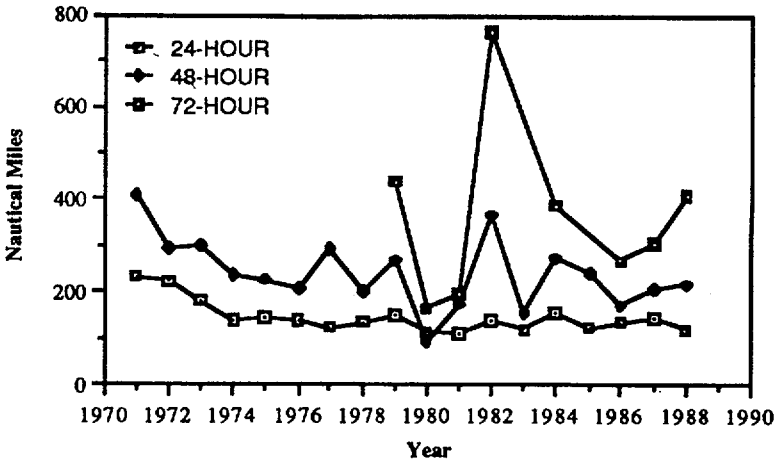



Figure 5-4. Annual mean forecast errors (nm) for all significant tropical cyclones in the North Indian Ocean.

TABLE 5-6A

**FORECAST ERROR SUMMARY (ERRORS IN NM)**
**SOUTH PACIFIC AND SOUTH INDIAN OCEANS**
**1988 SIGNIFICANT TROPICAL CYCLONES**

| TROPICAL CYCLONE | INITIAL POSIT ERROR | 24-HR FCST ERROR | 24-HOUR ALONG-TRACK MEAN* | 24-HOUR ALONG-TRACK MEDIAN | 24-HOUR CROSS-TRACK MEAN* | 24-HOUR CROSS-TRACK MEDIAN | 48-HR FCST ERROR | 48-HOUR ALONG-TRACK MEAN* | 48-HOUR ALONG-TRACK MEDIAN | 48-HOUR CROSS-TRACK MEAN* | 48-HOUR CROSS-TRACK MEDIAN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TC 01S | 33 | 125 | 56 | 9 | 98 | 24 | 216 | 148 | 84 | 137 | 71 |
| TC 02S | 21 | 57 | 54 | ** | 18 | ** | *** | *** | *** | *** | *** |
| TC 03S | 34 | 128 | 88 | ** | 73 | ** | 273 | 176 | ** | 164 | ** |
| TC 04P | 58 | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| TC 05S | 39 | 158 | 125 | ** | 81 | ** | 517 | 507 | ** | 98 | ** |
| TC 06P | 63 | 242 | 212 | -212 | 94 | 50 | 433 | 364 | ** | 193 | ** |
| TC 07P | 25 | 113 | 59 | -6 | 78 | -28 | 198 | 112 | ** | 139 | ** |
| TC 08S | 16 | 60 | 58 | ** | 13 | ** | 75 | 60 | ** | 41 | ** |
| TC 09S | 37 | 115 | 76 | -68 | 59 | -12 | 233 | 166 | ** | 115 | ** |
| TC 10S | 25 | 179 | 92 | ** | 140 | ** | 430 | 390 | ** | 161 | ** |
| TC 11S | 26 | 133 | 89 | -22 | 79 | -31 | 283 | 182 | -41 | 193 | -42 |
| TC 12P | 79 | 206 | 109 | ** | 55 | ** | 234 | 183 | ** | 132 | ** |
| TC 13P | 26 | 157 | 122 | -89 | 102 | 31 | 337 | 190 | -66 | 251 | 19 |
| TC 14S | 21 | 111 | 77 | ** | 67 | ** | 269 | 184 | ** | 153 | ** |
| TC 15P | 58 | 158 | 121 | ** | 77 | ** | 558 | 487 | ** | 222 | ** |
| TC 16S | 32 | 168 | 117 | -50 | 112 | -10 | 299 | 188 | -56 | 185 | 4 |
| TC 17S | 21 | 205 | 108 | ** | 166 | ** | 375 | 301 | ** | 160 | ** |
| TC 18S | 20 | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| TC 19P | 22 | 118 | 95 | ** | 51 | ** | 292 | 275 | ** | 84 | ** |
| TC 20S | 18 | 139 | 11 | ** | 139 | ** | 277 | 276 | ** | 17 | ** |
| TC 21S | 33 | 207 | 191 | ** | 66 | ** | *** | *** | *** | *** | *** |
| AVERAGES | 34 | 146 | 98 | -63 | 83 | 3 | 290 | 246 | -20 | 144 | 13 |

* THE MEAN WAS COMPUTED FROM ABSOLUTE VALUES.
** THE MEDIAN WAS NOT COMPUTED FOR INSTANCES OF TEN CASES OR LESS.
*** NOT ENOUGH WARNINGS WERE ISSUED TO VERIFY THE FORECAST.

SEE TABLE 5-1B FOR EXPLANATIONS OF THE TERMS MEAN, MEDIAN, ALONG-TRACK ERROR AND CROSS-TRACK ERROR.

TABLE 5-6B

**SOUTH PACIFIC AND SOUTH INDIAN OCEANS**
**NUMBER OF WARNINGS**

| TROPICAL CYCLONE | | INITIAL POSITION | 24-HOUR FORECAST | 48-HOUR FORECAST |
|---|---|---|---|---|
| TC-01S | ----- | 20 | 18 | 15 |
| TC-02S | ----- | 5 | 1 | 0 |
| TC-03S | ARINY | 10 | 7 | 6 |
| TC-04P | ----- | 2 | 0 | 0 |
| TC-05S | BERNANDRO | 11 | 9 | 1 |
| TC-06P | AGI | 3 | 1 | 0 |
| TC-06P | AGI* | 12 | 5 | 2 |
| TC-07P | ANNE | 14 | 6 | 3 |
| TC-08S | CALIDERA | 5 | 2 | 1 |
| TC-09S | DOAZA | 7 | 3 | 1 |
| TC-09S | DOAZA* | 11 | 5 | 2 |
| TC-10S | FREDERIC | 6 | 2 | 1 |
| TC-11S | GWENDA** | 16 | 7 | 3 |
| TC-12P | CHARLIE | 9 | 3 | 2 |
| TC-12P | CHARLIE* | 3 | 0 | 0 |
| TC-13P | BOLA | 20 | 9 | 4 |
| TC-14S | ----- | 6 | 3 | 1 |
| TC-15P | CILLA*** | 6 | 2 | 1 |
| TC-16S | GASITAO | 16 | 7 | 3 |
| TC-17S | ----- | 7 | 3 | 1 |
| TC-18S | HELY | 3 | 1 | 0 |
| TC-19P | DOVI | 12 | 5 | 2 |
| TC-20S | IARISENA | 3 | 1 | 0 |
| TC-21S | ----- | 3 | 1 | 0 |
| TOTALS | | 210 | 101 | 49 |

* REGENERATED
** ALSO NAMED EZENINA
*** NWOC SYSTEM

TABLE 5-7A

**ANNUAL MEAN FORECAST ERRORS (NM)**
**SOUTH PACIFIC AND SOUTH INDIAN OCEANS**

| YEAR | 24-HOUR FORECAST | 24-HOUR RIGHT-ANGLE | 48-HOUR FORECAST | 48-HOUR RIGHT-ANGLE |
|---|---|---|---|---|
| 1981 | 165 | 119 | 315 | 216 |
| 1982 | 144 | 91 | 274 | 174 |
| 1983 | 154 | 84 | 288 | 150 |
| 1984 | 133 | 73 | 231 | 124 |
| 1985 | 138 | 78 | 242 | 133 |
| 1986 | 133 | ** | 268 | ** |
| 1987 | 145 | ** | 280 | ** |
| 1988 | 146 | ** | 290 | ** |

** IN 1986, RIGHT-ANGLE ERROR WAS REPLACED BY CROSS-TRACK ERROR. SEE TABLE 5-1B FOR AN EXPLANATION OF CROSS-TRACK ERROR.

TABLE 5-7B

**1988 MEAN FORECAST,**
**ALONG-TRACK AND CROSS-TRACK ERRORS (NM)**
**SOUTH PACIFIC AND SOUTH INDIAN OCEANS**

| TIME | FORECAST ERROR | ALONG-TRACK ERROR MEAN | ALONG-TRACK ERROR MEDIAN | CROSS-TRACK ERROR MEAN | CROSS-TRACK ERROR MEDIAN |
|---|---|---|---|---|---|
| 24-HOUR | 146 | 101 | -62 | 86 | -1 |
| 48-HOUR | 290 | 203 | -100 | 166 | -25 |

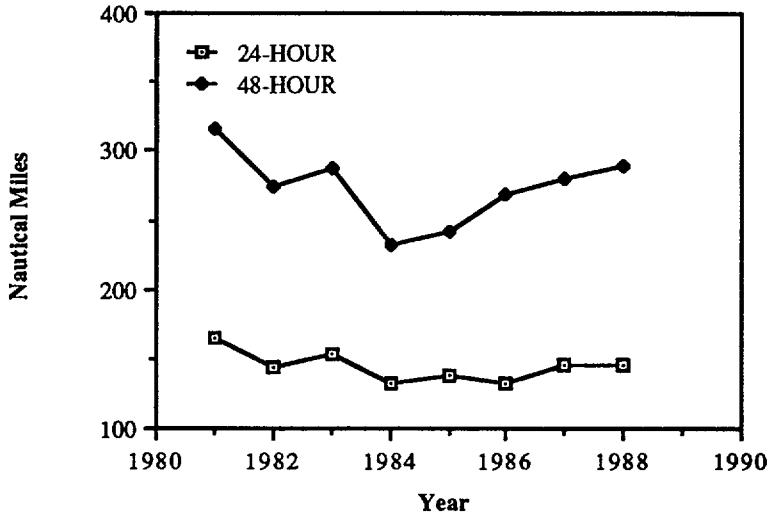



Figure 5-5. Annual mean forecast errors (nm) for all significant tropical cyclones in the South Pacific and South Indian Oceans

## 2. COMPARISON OF OBJECTIVE TECHNIQUES

a. GENERAL

Objective techniques used by JTWC are divided into five main categories:

(1) Extrapolation;

(2) Climatological and Analog Techniques;

(3) Model Output Statistics;

(4) Dynamic Models;

(5) Empirical and Analytical Techniques;

In September 1981, JTWC began to initialize its array of objective forecast techniques (described below) on the six-hour old preliminary best track position (an interpolative process) rather than the forecast (partially extrapolated) warning position, e.g. the 0600Z warning is now supported by objective techniques developed from the 0000Z preliminary best track position. This operational change has yielded several advantages:

(1) Techniques can now be requested much earlier in the warning development process, i.e. as soon as the track can be approximated by one or more fix positions after the valid time of the previous warning;

(2) Receipt of these techniques is virtually assured prior to the development of the next warning; and

(3) Improved (mean) forecast accuracy. This latter aspect arises because JTWC now has more reliable approximation of the short-term tropical cyclone movement. Further, since most of the objective techniques are biased towards persistence, this new procedure optimizes their performance and provides more consistent guidance on short-term movement, indirectly yielding a more accurate initial position estimate as well as lowering 24-hour forecast errors.

b. Description of Objective Techniques

(1) XTRP -- Forecast positions for 24- and 48-hours are derived from the extension of a straight line which connects the most recent and 12-hour old preliminary best track positions.

(2) CLIM -- A climatological aid providing 24-, 48-, and 72-hour tropical cyclone forecast positions (and intensity changes in the western North Pacific) based upon the position of the tropical cyclone. The output is based upon data records from 1945 to 1981 for the western North Pacific Ocean and 1900 to 1981 for the North Indian Ocean.

(3) HPAC -- Forecast positions are generated from a blend of climatology and persistence. The 24-, 48- and 72-hour positions are equally weighted between climatology and persistence. Persistence is a straight line extension of a line connecting the current and 12-hour old positions. Climatology is based on data from 1945 to 1981 for the western North Pacific Ocean and 1900 to 1981 for the North Indian Ocean.

(4) CLIPER -- A statistical regression technique based on climatology, current intensity, position and past movement. This technique is used as a crude measure of real forecast skill when verifying forecast accuracy.

(5) COSMOS -- A Model Output Statistics (MOS) routine based on the geostrophic steering at the 850-, 700-, and 500-mb levels. The steering is derived from the HATTRACK point advection model run on Global prognostic fields from the FLENUM-OCEANCEN's NOGAPS prediction system. The MOS forecast is then blended with the 6-hour past movement to generate the forecast

track.

(6) Colorado State University Model (CSUM) -- A statistical-dynamic method developed by Matsumoto (1984) utilizes synoptic and persistence predictors by discretizing the forecast timeframe into three 24-hour time steps. Climatology is incorporated into the forecast via a stratification scheme based on the position of the tropical cyclone relative to the 500 mb subtropical ridge. Depending on whether the tropical cyclone is south, on, or north of the ridge, three sets of regression equations are used to determine the north-south and east-west displacements

(7) One-way Interactive Tropical Cyclone Model (OTCM) -- A coarse-mesh, three-layer in the vertical, primitive equation model with a 205 km grid spacing over a 6400 x 4700 km domain. The model's fields are computed around a bogused, digitized cyclone vortex using FLENUMOCEANCEN's Numerical Variational Analysis (NVA) or NOGAPS prognostic fields for the specified valid time. The past motion of the tropical cyclone is compared to initial steering fields and a bias correction is computed and applied to the model. FLENUMOCEANCEN's NOGAPS global prognostic fields are used at 12-hour intervals to update the model's boundaries. The resultant forecast positions are derived by locating the 850 mb vortex at six-hour intervals to 72-hours.

(8) TAPT -- An empirical technique which utilizes upper-tropospheric wind fields to estimate acceleration associated with the tropical cyclone's interaction with the mid-latitude westerlies. It includes guidelines for the duration of acceleration, upper-limits, and probable path of the cyclone.

(9) TYAN -- An updated analog program which combines the earlier versions TYFN 75 and INJAN 74. The program scans a 30-year climatology with a similar history (within a specified acceptance envelope) to the current tropical cyclone. For the western North Pacific Ocean, three forecasts of position and intensity are provided for 24-, 48-, and 72-hours: RECR - a weighted mean of all tropical cyclones which were categorized as "recurving" during their best track period; STRA - a weighted mean of all accepted tropical cyclones which were categorized as moving "straight" (westward) during their best track period: TOTL - a weighted mean of all accepted tropical cyclones, including those used in the RECR and STRA forecast. For the North Indian Ocean, a single (total) forecast track is provided for the 12-hour intervals to 72-hours.

(10) DVORAK -- An estimation of tropical cyclone's current and 24-hour forecast intensity is made from interpolation of satellite imagery (DVORAK, 1984) and provided to the forecaster. These intensity estimates are used in conjunction with other intensity related data and trends to forecast tropical cyclone intensity.

(11) HOLLAND/MARTIN -- The technique adapts an earlier work (Holland, 1980) and specifically addresses the need for realistic 30-, 50- and 100-kt wind radii around tropical cyclones. It solves equations for basic gradient wind relations within the tropical cyclone area, using input parameters obtained from enhanced infrared satellite imagery. For the first time, diagnosis also includes an asymmetric area of winds caused by tropical cyclone movement. Size and intensity parameters are also used to diagnose internal steering components of tropical cyclone motion known collectively as "Beta-drift". The Holland/Martin wind radii technique replaces the more general Huntley (1980) technique.

c. Testing and Results

A comparison of selected techniques is included in Table 5-8 for all western North Pacific tropical cyclones, Table 5-9 for all North Indian Ocean tropical cyclones and Table 5-10 for the southern hemisphere. In these tables, " x-axis " refers to techniques listed vertically. For example (Table 5-8) in the 273 cases available for a (homogeneous) comparison, the

average forecast error at 24-hours was 130 nm (241 km) for TOTL and 137 nm (254 km) for RECR. The difference of 7 nm (13 km) is shown in the lower right. (Differences are not always exact, due to computational round-off which occurs for each of the cases available for comparison).

TABLE 5-8

# 1988 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE WESTERN NORTH PACIFIC OCEAN

## 24-HOUR MEAN FORECAST ERROR (NM)

| | JTWC | | CLIP | | OTCM | | CSUM | | RECR | | TOTL | | COSM | | HPAC | | CLIM | | XTRP | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JTWC | 373 | 114 | | | | | | | | | | | | | | | | | | |
| | 114 | 0 | | | | | | | | | | | | | | | | | | |
| CLIP | 334 | 114 | 334 | 132 | | | | | | | | | | | | | | | | |
| | 132 | 18 | 132 | 0 | | | | | | | | | | | | | | | | |
| OTCM | 345 | 113 | 323 | 133 | 345 | 124 | | | | | | | | | | | | | | |
| | 124 | 11 | 127 | -6 | 124 | 0 | | | | | | | | | | | | | | |
| CSUM | 287 | 114 | 284 | 130 | 280 | 125 | 287 | 121 | | | | | | | | | | | | |
| | 121 | 7 | 119 | -11 | 122 | -3 | 121 | 0 | | | | | | | | | | | | |
| RECR | 273 | 113 | 272 | 124 | 264 | 126 | 246 | 122 | 273 | 137 | | | | | | | | | | |
| | 137 | 24 | 136 | 12 | 136 | 10 | 136 | 14 | 137 | 0 | | | | | | | | | | |
| TOTL | 307 | 113 | 296 | 133 | 298 | 126 | 261 | 119 | 273 | 137 | 307 | 139 | | | | | | | | |
| | 139 | 26 | 133 | 0 | 139 | 13 | 136 | 17 | 130 | -7 | 139 | 0 | | | | | | | | |
| COSM | 346 | 111 | 323 | 131 | 335 | 124 | 283 | 121 | 266 | 136 | 296 | 140 | 346 | 131 | | | | | | |
| | 131 | 20 | 133 | 2 | 131 | 7 | 127 | 6 | 130 | -6 | 130 | -10 | 131 | 0 | | | | | | |
| HPAC | 349 | 113 | 332 | 133 | 338 | 125 | 286 | 119 | 273 | 137 | 304 | 137 | 338 | 130 | 349 | 131 | | | | |
| | 131 | 18 | 128 | -5 | 132 | 7 | 129 | 10 | 128 | -9 | 131 | -6 | 132 | 2 | 131 | 0 | | | | |
| CLIM | 350 | 113 | 333 | 133 | 338 | 126 | 286 | 121 | 273 | 137 | 304 | 137 | 339 | 131 | 348 | 131 | 350 | 178 | | |
| | 178 | 65 | 170 | 37 | 179 | 53 | 175 | 54 | 168 | 31 | 179 | 42 | 179 | 48 | 178 | 47 | 178 | 0 | | |
| XTRP | 355 | 112 | 334 | 132 | 343 | 124 | 285 | 119 | 273 | 137 | 307 | 139 | 344 | 130 | 348 | 131 | 349 | 177 | 355 | 130 |
| | 130 | 18 | 130 | -2 | 130 | 6 | 131 | 12 | 127 | -10 | 127 | -12 | 129 | -1 | 129 | -2 | 129 | -48 | 130 | 0 |

| NUMBER OF CASES | X-AXIS TECHNIQUE ERROR |
|---|---|
| Y-AXIS TECHNIQUE ERROR | ERROR DIFFERENCE (Y-X) |

## 48-HOUR MEAN FORECAST ERROR (NM)

| | JTWC | | CLIP | | OTCM | | CSUM | | RECR | | TOTL | | COSM | | HPAC | | CLIM | | XTRP | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JTWC | 262 | 216 | | | | | | | | | | | | | | | | | | |
| | 216 | 0 | | | | | | | | | | | | | | | | | | |
| CLIP | 238 | 219 | 249 | 260 | | | | | | | | | | | | | | | | |
| | 267 | 48 | 260 | 0 | | | | | | | | | | | | | | | | |
| OTCM | 242 | 215 | 236 | 256 | 253 | 220 | | | | | | | | | | | | | | |
| | 221 | 6 | 226 | -30 | 220 | 0 | | | | | | | | | | | | | | |
| CSUM | 197 | 216 | 206 | 256 | 204 | 219 | 208 | 238 | | | | | | | | | | | | |
| | 242 | 26 | 239 | -17 | 239 | 20 | 238 | 0 | | | | | | | | | | | | |
| RECR | 191 | 217 | 201 | 244 | 195 | 227 | 183 | 243 | 201 | 261 | | | | | | | | | | |
| | 266 | 49 | 261 | 17 | 259 | 32 | 265 | 22 | 261 | 0 | | | | | | | | | | |
| TOTL | 216 | 218 | 219 | 261 | 218 | 222 | 191 | 237 | 201 | 261 | 226 | 282 | | | | | | | | |
| | 285 | 67 | 270 | 9 | 281 | 59 | 281 | 44 | 270 | 9 | 282 | 0 | | | | | | | | |
| COSM | 245 | 213 | 239 | 258 | 244 | 222 | 205 | 239 | 196 | 258 | 216 | 285 | 256 | 276 | | | | | | |
| | 283 | 70 | 284 | 26 | 269 | 47 | 259 | 20 | 264 | 6 | 271 | -14 | 276 | 0 | | | | | | |
| HPAC | 247 | 215 | 246 | 261 | 246 | 222 | 207 | 237 | 200 | 257 | 222 | 272 | 248 | 276 | 258 | 240 | | | | |
| | 243 | 28 | 237 | -24 | 238 | 16 | 236 | -1 | 233 | -24 | 234 | -38 | 241 | -35 | 240 | 0 | | | | |
| CLIM | 247 | 215 | 247 | 260 | 245 | 222 | 206 | 238 | 200 | 257 | 222 | 272 | 248 | 275 | 257 | 239 | 258 | 289 | | |
| | 297 | 82 | 277 | 17 | 290 | 68 | 280 | 42 | 270 | 13 | 282 | 10 | 295 | 20 | 290 | 51 | 289 | 0 | | |
| XTRP | 254 | 215 | 249 | 260 | 252 | 220 | 207 | 238 | 201 | 261 | 226 | 282 | 255 | 276 | 257 | 239 | 258 | 289 | 265 | 292 |
| | 291 | 76 | 294 | 34 | 291 | 71 | 298 | 60 | 289 | 28 | 288 | 6 | 291 | 15 | 291 | 52 | 291 | 2 | 292 | 0 |

JTWC - OFFICIAL JTWC FORECAST
CLIP - CLIPER (CLIMATOLOGY AND PERSISTENCE)
OTCM - ONE-WAY TROPICAL CYCLONE MODEL
CSUM - COLORADO STATE UNIVERSITY MODEL
TOTL - TOTAL ANALOG (TYAN 78)
CLIM - CLIMATOLOGY
HPAC - HALF CLIMATOLOGY AND PERSISTENCE BLEND
XTRP - 12-HOUR EXTRAPOLATION

## 72-HOUR MEAN FORECAST ERROR (NM)

| | JTWC | | CLIP | | OTCM | | CSUM | | RECR | | TOTL | | COSM | | HPAC | | CLIM | | XTRP | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JTWC | 183 | 315 | | | | | | | | | | | | | | | | | | |
| | 315 | 0 | | | | | | | | | | | | | | | | | | |
| CLIP | 167 | 323 | 182 | 398 | | | | | | | | | | | | | | | | |
| | 413 | 90 | 398 | 0 | | | | | | | | | | | | | | | | |
| OTCM | 160 | 305 | 163 | 373 | 175 | 309 | | | | | | | | | | | | | | |
| | 309 | 4 | 315 | -58 | 309 | 0 | | | | | | | | | | | | | | |
| CSUM | 134 | 325 | 148 | 392 | 144 | 306 | 149 | 367 | | | | | | | | | | | | |
| | 378 | 53 | 369 | -23 | 366 | 60 | 367 | 0 | | | | | | | | | | | | |
| RECR | 128 | 321 | 143 | 357 | 136 | 308 | 129 | 371 | 143 | 431 | | | | | | | | | | |
| | 436 | 115 | 431 | 74 | 433 | 125 | 444 | 73 | 431 | 0 | | | | | | | | | | |
| TOTL | 141 | 328 | 154 | 393 | 143 | 313 | 133 | 367 | 143 | 431 | 156 | 446 | | | | | | | | |
| | 451 | 123 | 443 | 50 | 448 | 135 | 465 | 98 | 440 | 9 | 446 | 0 | | | | | | | | |
| COSM | 173 | 307 | 176 | 388 | 170 | 309 | 146 | 368 | 139 | 424 | 150 | 445 | 188 | 505 | | | | | | |
| | 520 | 213 | 518 | 130 | 466 | 157 | 455 | 87 | 445 | 21 | 487 | 42 | 505 | 0 | | | | | | |
| HPAC | 172 | 311 | 178 | 389 | 168 | 303 | 146 | 361 | 140 | 406 | 153 | 424 | 181 | 491 | 187 | 350 | | | | |
| | 359 | 48 | 349 | -40 | 344 | 41 | 348 | -13 | 337 | -69 | 344 | -80 | 348 | -143 | 350 | 0 | | | | |
| CLIM | 172 | 311 | 178 | 389 | 168 | 303 | 146 | 361 | 140 | 406 | 153 | 424 | 181 | 491 | 187 | 350 | 187 | 377 | | |
| | 388 | 77 | 361 | -28 | 373 | 70 | 356 | -5 | 343 | -63 | 358 | -66 | 379 | -112 | 377 | 27 | 377 | 0 | | |
| XTRP | 179 | 314 | 182 | 398 | 175 | 309 | 149 | 367 | 143 | 431 | 156 | 446 | 188 | 505 | 187 | 350 | 187 | 377 | 194 | 480 |
| | 482 | 168 | 482 | 84 | 478 | 169 | 499 | 132 | 486 | 55 | 490 | 44 | 475 | -30 | 477 | 127 | 477 | 100 | 480 | 0 |

TABLE 5-9

## 1988 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTHERN INDIAN OCEAN

### 24-HOUR MEAN FORECAST ERROR (NM)

| | JTWC | | OTCM | | CSUM | | HPAC | | CLIM | | XTRP | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JTWC | 30 | 120 | | | | | | | | | | |
| | 120 | 0 | | | | | | | | | | |
| OTCM | 30 | 120 | 32 | 103 | | | | | | | | |
| | 106 | -14 | 103 | 0 | | | | | | | | |
| CSUM | 28 | 117 | 30 | 101 | 30 | 207 | | | | | | |
| | 220 | 103 | 207 | 106 | 207 | 0 | | | | | | |
| HPAC | 30 | 120 | 32 | 103 | 30 | 207 | 32 | 112 | | | | |
| | 117 | -3 | 112 | 9 | 110 | -97 | 112 | 0 | | | | |
| CLIM | 30 | 120 | 32 | 103 | 30 | 207 | 32 | 112 | 32 | 116 | | |
| | 117 | -3 | 116 | 13 | 114 | -93 | 116 | 4 | 116 | 0 | | |
| XTRP | 29 | 122 | 31 | 104 | 29 | 202 | 31 | 113 | 31 | 118 | 31 | 130 |
| | 134 | 12 | 130 | 26 | 131 | -71 | 130 | 17 | 130 | 12 | 130 | 0 |

| NUMBER OF CASES | X-AXIS TECHNIQUE ERROR |
|---|---|
| Y-AXIS TECHNIQUE ERROR | ERROR DIFFERENCE (X-Y) |

### 48-HOUR MEAN FORECAST ERROR (NM)

| | JTWC | | OTCM | | CSUM | | HPAC | | CLIM | | XTRP | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JTWC | 18 | 219 | | | | | | | | | | |
| | 219 | 0 | | | | | | | | | | |
| OTCM | 18 | 219 | 20 | 211 | | | | | | | | |
| | 227 | 8 | 211 | 0 | | | | | | | | |
| CSUM | 17 | 220 | 19 | 216 | 19 | 539 | | | | | | |
| | 576 | 356 | 539 | 323 | 539 | 0 | | | | | | |
| HPAC | 18 | 219 | 20 | 211 | 19 | 539 | 20 | 202 | | | | |
| | 185 | -34 | 202 | -9 | 209 | -330 | 202 | 0 | | | | |
| CLIM | 18 | 219 | 20 | 211 | 19 | 539 | 20 | 202 | 20 | 162 | | |
| | 141 | -78 | 162 | -49 | 165 | -374 | 162 | -40 | 162 | 0 | | |
| XTRP | 17 | 225 | 19 | 220 | 18 | 527 | 19 | 208 | 19 | 167 | 19 | 265 |
| | 251 | 26 | 265 | 45 | 277 | -250 | 265 | 57 | 265 | 98 | 265 | 0 |

JTWC - OFFICIAL JTWC FORECAST
OTCM - ONE-WAY TROPICAL CYCLONE MODEL
CSUM - COLORADO STATE UNIVERSITY MODEL
TOTL - TOTAL ANALOG (TYAN 78)
CLIM - CLIMATOLOGY
HPAC - HALF CLIMATOLOGY AND PERSISTENCE BLEND
XTRP - 12-HOUR EXTRAPOLATION

### 72-HOUR MEAN FORECAST ERROR (NM)

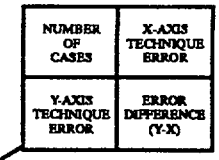
| | JTWC | | OTCM | | CSUM | | HPAC | | CLIM | | XTRP | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JTWC | 12 | 409 | | | | | | | | | | |
| | 409 | 0 | | | | | | | | | | |
| OTCM | 11 | 426 | 11 | 527 | | | | | | | | |
| | 527 | 101 | 527 | 0 | | | | | | | | |
| CSUM | 11 | 413 | 10 | 540 | 11 | 1043 | | | | | | |
| | 1043 | 630 | 1034 | 494 | 1043 | 0 | | | | | | |
| HPAC | 12 | 409 | 11 | 527 | 11 | 1043 | 12 | 298 | | | | |
| | 298 | -111 | 311 | -216 | 313 | -730 | 298 | 0 | | | | |
| CLIM | 12 | 409 | 11 | 527 | 11 | 1043 | 12 | 298 | 12 | 231 | | |
| | 231 | -178 | 235 | -292 | 233 | -810 | 231 | -67 | 231 | 0 | | |
| XTRP | 11 | 428 | 10 | 557 | 10 | 1037 | 11 | 312 | 11 | 237 | 11 | 399 |
| | 399 | -29 | 421 | -136 | 433 | -604 | 399 | 87 | 399 | 162 | 399 | 0 |

TABLE 5-10

## 1988 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE SOUTHERN HEMISPHERE

### 24-HOUR MEAN FORECAST ERROR (NM)

| | JTWC | | OTCM | | HPAC | | CLIM | | XTRP | |
|---|---|---|---|---|---|---|---|---|---|---|
| JTWC | 156 | 146 | | | | | | | | |
| | 146 | 0 | | | | | | | | |
| OTCM | 129 | 146 | 142 | 122 | | | | | | |
| | 125 | -21 | 122 | 0 | | | | | | |
| HPAC | 143 | 147 | 141 | 121 | 156 | 124 | | | | |
| | 126 | -21 | 121 | 0 | 124 | 0 | | | | |
| CLIM | 144 | 147 | 142 | 122 | 156 | 124 | 157 | 158 | | |
| | 160 | 13 | 154 | 32 | 158 | 34 | 158 | 0 | | |
| XTRP | 147 | 148 | 141 | 121 | 156 | 124 | 156 | 158 | 161 | 139 |
| | 136 | -12 | 134 | 13 | 136 | 12 | 136 | -22 | 139 | 0 |




### 48-HOUR MEAN FORECAST ERROR (NM)

| | JTWC | | OTCM | | HPAC | | CLIM | | XTRP | |
|---|---|---|---|---|---|---|---|---|---|---|
| JTWC | 112 | 290 | | | | | | | | |
| | 290 | 0 | | | | | | | | |
| OTCM | 91 | 274 | 121 | 238 | | | | | | |
| | 237 | -37 | 238 | 0 | | | | | | |
| HPAC | 104 | 279 | 120 | 236 | 135 | 219 | | | | |
| | 226 | -53 | 219 | -17 | 219 | 0 | | | | |
| CLIM | 105 | 279 | 121 | 238 | 135 | 219 | 136 | 272 | | |
| | 270 | -9 | 272 | 34 | 271 | 52 | 272 | 0 | | |
| XTRP | 107 | 289 | 120 | 236 | 135 | 219 | 135 | 271 | 138 | 283 |
| | 294 | 5 | 277 | 41 | 280 | 61 | 280 | 9 | 283 | 0 |

JTWC - OFFICIAL JTWC FORECAST
OTCM - ONE-WAY TROPICAL CYCLONE MODEL
TOTL - TOTAL ANALOG (TYAN 78)
HPAC - HALF CLIMATOLOGY AND PERSISTENCE BLEND
CLIM - CLIMATOLOGY
XTRP - 12-HOUR EXTRAPOLATION

### 72-HOUR MEAN FORECAST ERROR (NM)

| | OTCM | | HPAC | | CLIM | | XTRP | |
|---|---|---|---|---|---|---|---|---|
| OTCM | 92 | 368 | | | | | | |
| | 368 | 0 | | | | | | |
| HPAC | 92 | 368 | 113 | 334 | | | | |
| | 329 | -39 | 334 | 0 | | | | |
| CLIM | 92 | 368 | 113 | 334 | 113 | 431 | | |
| | 444 | 76 | 431 | 97 | 431 | 0 | | |
| XTRP | 92 | 368 | 113 | 334 | 113 | 431 | 114 | 412 |
| | 405 | 37 | 415 | 81 | 415 | -16 | 412 | 0 |

Intentionally left blank.